Project NY 112 004-4
Technical Note N-274
27 September 1956

POWERED ARCTIC CARGO TRAILER OPERATIONAL TESTS IN SAND, MUD, AND SNOW

S. J. Weiss
K. Yamamoto
D. Taylor

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U. S. Naval Civil Engineering Research and Evaluation Laboratory
Port Hueneme, California

SUMMARY

An experimental Arctic Cargo Trailer of 15-ton capacity was developed by the Laboratory to negotiate rough and unstable arctic terrain in summer and winter. Its purpose is similar to the 15-ton capacity, military-type, full-track cargo trailer, but it has the added features of dual tandem pneumatic tires, removable tire-tracks, and a special, powered universal joint through which the trailer is powered by the take-off at the rear of a prime mover tractor. When powered, the tractor-trailer combination has a road speed of 21.6 ft/min. The trailer was tested in mud and sand at Port Hueneme, California, and in mud and snow at Fort Churchill, Canada. It has demonstrated considerable ability in sand, mud, and snow.

INTRODUCTION

Cargo hauling operations in the Arctic, as experienced in the Naval Petroleum Reserve No. 4, have shown the need for an improved cargo trailer. Existing tracked cargo trailers are considered to have limited utility in arctic regions. Their use in the thaw season is restricted by high ground pressures, and by low towing speeds in all seasons, especially when transporting heavy loads. The 20-ton Athey trailer has a ground pressure of 28 psi, and the 15 ton trailer 16 psi. These ground bearing pressures are much higher than those of the normal towing tractor which is usually around 10 psi.

In November 1950, the Bureau of Yards and Docks assigned Project NY 013 007-2 to the Laboratory for the development of an arctic cargo trailer, similar to the Athey wagon, and suitable for handling heavy cargo. The desired characteristics were a payload capacity of 15 to 20 tons, ground pressure of one to two psi, and capable of being towed at 15 mph.

DEVELOPMENT AND FABRICATION

The Laboratory prepared schematic sketches of a proposed Arctic Cargo Trailer, (see Figures 1 and 2). The schematics show an existing D8 Caterpillar tractor with a special power take-off, which is coupled through a universal joint to a gear train in the proposed trailer to drive the tracks. When the power take-off is in gear, the regular tractor transmission is not used. The PTO drives both the tractor and the trailer at a road speed of 21.6 fpm. The trailer is powered to provide additional tractive effort in difficult terrain, where the tractor alone would normally slip stall.

The schematics and desired characteristics of the proposed trailer were sent to several contractors for submittal of proposals for design and fabrication of a prototype unit.

A contract was awarded in April 1950 to Cook Bros. Equipment Company for a trailer with the following specifications.

1. Bogie Type: Dual chain drive. Single point suspension.
2. Axle Spacing: 56"
3. Axle Capacity: 20,000 lb each, 2 axles.

4.	Wheels:	20 x 10.00, 10°, 11-1/4" B.C., 8-7/8" dish, 17-3/4" spacing, Wheel No. WE-66550-B, Budd type.
5.	Tires:	14.00 x 20, 12 ply, tactical
6.	Tread:	84-15/16" center to center of duals.
7.	Over-all Width:	117-7/8" outside to outside of dual tires (with tires and wheels described in items 4 and 5 above).
8.	Brakes:	16-1/2 x 6 with 3/4" block lining. Mechanical type with 9" B.W. Diaphragms and Slack Adjusters.
9.	Jackshaft:	Double reduction ratio 9.02-1. Cook Bros. D-160-A.
10.	Sprockets:	19 teeth drive, 43 teeth driven, 1-3/4 pitch, mud and snow type, ratio 2.26-1.
11.	Drop Gear Case:	Ratio 5.66; which combined with 9.02 differential ratio and 2.26 sprocket ratio gives a full gear ratio of 115.38 to produce a road speed of 21.6 fpm.
12.	Body Type:	Stake. Wood and steel construction with removable ends and sides, hardwood floor, and steel skid strips.
13.	Body Size:	15'-0" long x 9'-10"wide with 5'-0" stake sides and ends.
14.	Body Stabilizers:	Mechanical-type manual operation and control.
15.	Draw Bar Support:	Manually adjusted type
16.	Paint:	International Orange Industrial, two coats. Wood portion of the trailer body impregnated with a good quality of commercial preservative.
17.	Hub Spacers:	One set of four 1"-thick hub spacers, and the required longer wheel studs, supplied for installation when standard tire chains are applied to the tires.
18.	Weight:	12,400 lb (without Powered Universal Joint or tire tracks).
19.	Deck Loading Height:	62"

The powered universal joint was designed at the Laboratory. This item and the tire tracks were purchased separate from the trailer.

The complete Arctic Cargo Trailer was fabricated in accordance with the following contracts:

Contract No. N160s-4755 Amt. $36,500.00
Prototype Wheeled Cargo Trailer
Cook Bros. Equipment Co.
Los Angeles, California
Issued: 3 April 1951 Delivered: 5 June 1952

Contract No. N160s-8485 Amt. $ 4,675.00
Powered Universal Joint
Engineering Products Co.
Los Angeles, California
Issued: 19 March 1952 Delivered: 9 February 1953

Contract No. N160s-8447 Amt. $ 1,456.00
Galanot Tire Tracks, 2-30" wide,
single row connectors
Galanot Track and Machine Co.
Alliance, Ohio
Issued: 19 March 1952 Delivered: 17 December 1952

Contract No. N160s-14453(P) Amt. $ 2,537.70
Galanot Tire Tracks, 2-38" wide,
double row connectors
The Union Chain and Manufacturing Co.
Sandusky, Ohio
Issued: 20 November 1952 Delivered: 15 January 1954
(This set of tracks was used in the tests at Fort Churchill, Canada.)

In addition, the following units completed the tractor-trailer assembly:

Caterpillar D8 Tractor with Dozer, Ser. No. 2U5582
Caterpillar Tractor Company
Peoria, Illinois

Power Take-off Transmission CW 240-A1, Ser. No. 118
Wood Manufacturing Company
North Hollywood, California

Morse Formsprag Over-running Clutch No. FS-700
Morse Chain Company
Detroit, Michigan

Prior to the preliminary tests of the tractor-trailer unit, the over-running clutch was installed between the

trailer drop gear case and axle by the Laboratory shops to eliminate back driving of the Universal Joint when the trailer is not powered and is towed forward. In reverse and unpowered, back driving of the Universal Joint is accepted in the prototype.

Figures 3 through 8 show various parts of the tractor-trailer unit prior to preliminary tests.

CHARACTERISTICS OF THE ASSEMBLED TRACTOR TRAILER UNIT

The road speed of the unit is 21.6 fpm (.25 mph) when power is applied to the trailer and tractor through the power take-off. The unit can travel at all forward speeds provided by the tractor transmission when the trailer is not powered. When the unit is in reverse, power cannot be applied through the power take-off, so that the tractor transmission speeds are used. However, reverse ground speed is to be held to a minimum because the Powered Universal Joint, which normally turns over at 212 rpm, can be back-driven by the trailer track motion at speeds up to 2000 rpm.

The tractor ground bearing pressure with dozer and power take-off installed is about 10.3 psi. The trailer with 15-ton load has 13.0 psi ground bearing pressure using the 30" wide Galanot tracks, and 10.0 psi using the 38" wide tracks.

The Powered Universal joint transmits torque only. All axial forces are carried by the towbar connection between the vehicles.

TESTS

Preliminary tests were made in comparison to the performance of a 15-ton Athey wagon. First on prepared sand slopes at the Military Training Area, Construction Battalion Center, Port Hueneme; then in the mud of a tidewater slough near the Laboratory Equipment Compound at Point Mugu. Results of these tests appear in Appendix A.

Winter tests of the trailer were conducted at Fort Churchill, Manitoba, Canada, by the U. S. Army Corps of Engineers Climatic Field Test Team under the supervision of a Laboratory engineer. The memorandum of procedure for these tests and the results are in Appendix B.

The summer tests in tundra (muskeg) were performed by the Corps of Engineers Climatic Field Test Team. Their report with a supplementary analysis of the ground at the test site by a group from Cornell University are given in Appendix C.

CONCLUSIONS

The 15-ton Arctic Cargo Trailer is inferior to a 15-ton Athey Wagon when used as a towed unit. When powered, it outperformed the Athey Wagon in negotiating sand and mud, over slopes and obstacles.

The unit demonstrates considerable ability in snow. It is also able to negotiate muskeg which is impassable when the trailer is used as a towed unit.

Side slippage of the Galanot Tire Tracks on side hills and on turns is partially caused by the track connectors being unsuitable for use with the rounded tread of the Tactical Cross Country Tires.

The single powered speed of 21.6 fpm is considered unsatisfactory.

RECOMMENDATIONS

In the future, if a review of requirements indicates there is sufficient justification for further development of the Arctic Cargo Trailer, the following programs are recommended for consideration:

Minimum

1. Decrease internal rolling resistance of trailer, when towed, by providing means to disconnect the power train from the trailer wheels.

2. Provide the ability to transmit power to the trailer at two road speeds, .25 and 1.6 mph.

3. Provide a tire track that will not be susceptible to side slippage on the wheels (change of tire section could be solution).

Maximum

1. Develop a powered trailer that would be in synchronization at all speeds of the transmission of the powering tractor.

2, The trailer would be tracked (no tires). Use of Caterpillar track and suspension components for the trailer running gear are suggested to insure comparable service life of the tractor and trailer.

APPENDIX A

REPORT OF PRELIMINARY TESTS

ON ARCTIC CARGO TRAILER

1 December 1953

MEMORANDUM

Project YD 512-21

REPORT OF PRELIMINARY TESTS
ARCTIC CARGO TRAILER

by S. J. Weiss

Comparative tests in sand and mud were conducted with the experimental Arctic Cargo Trailer and the 15-ton Athey Wagon during the period 5-12 November 1953. The sand tests were conducted on the prepared slopes in the Military Training Area while the mud tests were performed adjacent to the slough near the equipment compound at Point Mugu. Both trailers were coupled to D-8 Caterpillar Tractors (Figures 9 and 10).

The sand tests on the experimental unit were performed both with and without the Galanot tire tracks. The mud tests were carried out with tracks installed. Tire pressure of the experimental unit was 35 psi. The tracks on both the Athey wagon and the experimental trailer were 30" wide.

The sand tests conducted on the 25% prepared slope (see Figure 11) gave the following results:

Test Unit	Cargo Load	Tracks		Condition of Trailer		Result	
		With	Without	Towed	Powered	Success	Failure
Powered Trailer	10 tons	x		x		x	
Athey Wagon	10 tons	x		x		x	
Powered Trailer	10 tons		x	x			x
Powered Trailer	10 tons		x		x	x	
Athey Wagon	15 tons	x		x		x	
Powered Trailer	15 ton	x		x			x
Powered Trailer	15 tons	x			x	x	

Further sand tests on a 35% slope demonstrated that when power is transmitted to the trailer of the experimental unit. this combination is vastly superior in slope climbing ability to the standard D-8 Tractor - Unpowered Athey Wagon combination (Figures 12 and 13).

During these trials, it became evident that it was required to raise the bed of the experimental trailer in order to allow greater track clearance (Figure 14) and that some modification of the powered universal joint was required in order to allow increased articulation in the vertical plane (Figure 15). Improvement in the tire track was also dictated in order to prevent side slippage of the tracks when turning or on side hills (Figures 16 and 17). The modification in track clearance and joint articulation was accomplished at the Laboratory Shops.

The mud tests demonstrated that the experimental trailer could carry 15 tons of cargo on repeated passes over the soft ground adjacent to a slough. This was accomplished without transmitting power to the trailer. The experimental unit was able to climb out of the mud onto the hard bank when power was transmitted to the trailer. The Athey Wagon was unable to duplicate this maneuver (see Figures 18, 19 and 20).

The tests to date indicate that:

a. The experimental trailer has a higher rolling resistance (caused by the necessity of turning over the drive chains and gearing) than the Athey Wagon and therefore is somewhat inferior to the Athey Wagon when utilized as a towed unit only.

b. When power is transmitted to the experimental trailer, its performance is vastly superior to that obtained without power and the experimental unit can markedly outperform the D-8 Athey Wagon combination insofar as the traversing of slopes and ground obstacles is concerned.

It is recommended that, after the snow tests are conducted this winter at Fort Churchill with a revised Galanot track that will prevent side slippage of the track on the dual wheels, consideration be given to continued development of the experimental trailer that will allow:

a. Decreased rolling resistance when towed by declutching the trailer drive mechanism from the wheels, and

b. The ability to transmit power to the trailer at a much higher road speed than the present 25 feet per minute.

APPENDIX B

MEMORANDUM OF PROCEDURE AND REPORT
OF TEST OF ARCTIC CARGO TRAILER AT
FORT CHURCHILL, CANADA, WINTER 1953-1954

U. S. NAVAL CIVIL ENGINEERING
RESEARCH AND EVALUATION LABORATORY
CONSTRUCTION BATTALION CENTER
Port Hueneme, California

NT4-59/YD 512-21
791/EJB/pan
15 Dec 1953

MEMORANDUM OF PROCEDURE, PROJECT NO. YD 512-21 JOB ORDER 70708

Subj: Arctic Cargo Trailer, Snow Tests of at Fort Churchill, Manitoba Canada, January and February 1954

1. GENERAL

The Bureau of Yards and Docks initiated the Project YD 512-21, "Arctic Cargo Trailer," for the study and development of a cargo trailer that possessed the basic requirements for military operation in arctic areas for year round use. The present Arctic Cargo Trailer is believed to be the first effort to meet the requirements for operation in sand, snow, mud, ice and tundra. It was designed and constructed under the supervision of the Naval Civil Engineering Research and Evaluation Laboratory. Tests in mud and sand have been conducted at Port Hueneme, and the present instructions cover testing in snow and on ice.

2. PURPOSE

These tests have for their purpose the testing of the prototype Arctic Cargo Trailer under arctic conditions in snow and on ice, to enable an analysis of its performance.

3. DESCRIPTION

The prototype trailer is 22 feet 6 inches long by 9 feet 6 inches wide and 5 feet high. It has a 9 by 15 foot platform with a stake body. It weighs 6 tons and has a 15 ton maximum capacity, net. The unit is wheel mounted and features a two axle bogie drive with power obtained through a propeller shaft attached to the power take-off of the prime mover. This particular take-off system is designed for use with a Caterpillar D-8 crawler tractor, and was manufactured by the Pettibone-Wood Manufacturing Company of Los Angeles, California Power may be supplied to the trailer either with or without powering the tractor. The propeller shaft is detachable, a

feature permitting towing of the trailer behind military trucks and road tractors on surfaced roads. Wheels may be used in single or dual tandem. A detachable articulated track, the "Galanot" tire track, is provided for use with the dual tandem wheels.

4. TEST OBJECTIVES

The tests are designed to study the powered trailer-tractor performance when operating on snow and ice in the arctic to determine:

a. Mobility of tractor-powered trailer combination.
b. Tractive effort of tractor-powered trailer combination.
c. Maneuverability of tractor-powered trailer combination.

5. TEST PROCEDURE

a. Mobility Tests

(1) Select suitable snow-covered level site.
(2) Prepare tractor-powered trailer combination for operation with dual tandem wheels, with proper tire deflection.
(3) With power take-off disengaged, select a stalling load for the tractor. Note performance conditions.
(4) With same load, speed and comparable (parallel) course, operate tractor with power to the trailer. When the trailer is powered, the tractor gears must always be placed in neutral, as the tractor receives its power through the take-off system, through a different gear ratio than is available through its own transmission. Compare performance.
(5) Repeat (4) with power trailer powered but without power to tractor (forward position of take-off shift lever, neutral on tractor gears).
(6) Repeat (3) to (5) using Galanot wheel tracks.
(7) Repeat (3) to (5) with single tandem wheels.

b. Maneuverability Tests

(1) Select suitable level snow covered site.
(2) Prepare wheels for 36,000 pound gross load (wheel deflection adjustment if necessary).

(3) With tractor powered, take-off disengaged: Operate equipment down stretch of level terrain at maximum possible speed; make normal turning, backing, and reverse turning operations; operate equipment on available slopes; when in reverse, backdrive of power take-off shaft occurs and very low speed must be maintained; operate equipment on roughest terrain it will negotiate, noting performance on all operations.
(4) Repeat (3) with take-off and tractor powered except for reversing.
(5) Repeat (3) and (4) with Galanot tracks attached.
(6) Repeat (3) with 8,000 pound gross load and single tandem wheels.

c. Tractive Effort Tests

(1) Prepare trailer with tandem wheels (duals), and 36,000 pound gross load.
(2) Provide braking vehicle (D-8 Caterpillar crawler tractor or equivalent), with attached dynamometer.
(3) With braking vehicle as load, and power transfer system disengaged, operate tractor in first gear.
(4) Operate tractor at rated engine speed, recording maximum drawbar load, speed, and by measurement, slip. Operate at lesser loads, recording slip and speed, with constant engine speed.
(5) Repeat (3) and (4) with tractor and trailer both powered.
(6) Repeat (3) to (6) with wheel tracks applied.
(7) Repeat (3) to (5) with single tandem wheels and 18,000 pound gross load.

6. EQUIPMENT AND MATERIAL

a. Prime Mover, a Caterpillar D-8 Crawler Tractor with power take-off and splined shaft, winterized.
b. Prototype Arctic Cargo Trailer.
* c. Dynamometer.
d. Tapes, stopwatches, and revolution counter.
e. Braking vehicle.
f. Galanot wheel tracks for dual tandem wheels.
* g. Photographic equipment.
h. Inclinometer.
i. Trailer load (stake body has been equipped for loading with water to be frozen into ice by inserting plywood panels).

* j. Tire inflating and pressure measuring equipment. Still and motion picture coverage of all tests shall be provided.

Note: Items marked with an asterisk were requested from ERDL.

E. J. BECK
Project Engineer

APPROVED

Director
Construction Division

Acting Head
Equipment Research Dept.

MEMORANDUM REPORT

TEST OF ARCTIC CARGO TRAILER AT FORT CHURCHILL, CANADA, WINTER 1953-1954

Project YD 512-21

By E. J. Beck

INTRODUCTION

An Arctic Cargo Trailer, designed to negotiate rough arctic terrain and unstable ground in both summer and winter, was developed by the Laboratory. Similar to the Athey Wagon of World War II in purpose, it has the added features of a removable track and powering from the prime mover, to facilitate movement when greater traction than that afforded by the prime mover is needed. Tests have been interrupted because of the failure of a rear axle, currently being replaced. Earlier tests in mud and sand at Port Hueneme have been reported on in a Memorandum Report on Project YD 512-21, dated 1 December 1953. Tests herein reported were made at Fort Churchill, Manitoba, Canada, in February 1954.

DESCRIPTION

The prototype Arctic Cargo Trailer, powered, Figure 21, has a 9' x 15' platform with a 60" loading height, weighs 12,000 pounds and has a 30,000 pound maximum net load.

It is equipped with a towing tongue, landing gear, rear towing drawbar, and a splined shaft drive from a special transmission on the rear of a D-8 Caterpillar tractor. The necessary speed ratio between the tractor and trailer during the power-to-the-trailer operation is maintained by powering both the trailer and final drive of the tractor from the special (Pettibone Wood Manufacturing Company, Los Angeles) power take-off transmission. When power is being supplied through the transmission, a much lower gear ratio than that afforded by the low gear of the tractor is available and is used. Progress of the unit, when powered, is therefore very slow. The trailer can be used on single or dual tandem pneumatic tires, or, for test, with experimental wrap-around "Galanot" tracks, Figure 21.

DISCUSSION

Early testing at Churchill was interrupted by fuel transfer difficulties in the diesel tractor. In establishing reliability of the fuel system once cleaned, approximately 12 hours of around-camp operation towing was accomplished with the trailer unloaded, but with the Galanot tracks applied.

A single, no-load run was made up a 15 degree slope south east of the North Camp, Fort Churchill on Saturday, February 13, 1954. With the D-8 alone pulling, snow was cut deeply and tracks slipped excessively even while the unit was mobile. Twice the tractor stopped, i.e., slippage was 100%. Each time the unit could, with the trailer powered, proceed with a minimum disturbance of snow, and no visible slippage. A fuel system failure at the top of the hill prevented further attempts on the slightly steeper slopes available. Figure 21 shows the tractor and trailer just after engine failure, about to descend the hill. Snow cover on the slope varied from a trace to 8 to 10 inches of wind-blown, packed dry snow.

Subsequent tests, during which movies were taken, were made about 1/4 mile south of South Camp, Fort Churchill, on an uneven but nearly level area. The trailer was loaded with 15 tons of steel. Maximum speeds of operation in a straight line both with and without power were obtained, using a stop watch on a 100 yard measured course. The average speed for three runs with power take-off disengaged was 8.4 feet per second, or 4.73 mph. With the trailer also powered, the speed was 0.46 feet per second, or 0.314 mph.

A 12 degree slope was subsequently negotiated under tractor power alone; in breaking over the crest of the hill, the landing gear of the trailer scraped and folded under.

An attempt was made to negotiate a steep, snow covered bank without power to the trailer. The tractor tracks slipped. When power was applied to the trailer, the tractor tracks and the left track of the trailer slipped, but the right track of the trailer did not. The engine torque available from the power take-off was applied to the right track of the trailer, and the rear axle of the trailer broke near the weld fastening the air brake (Figure 22). It is presumed that the failure was caused by the extreme bending forces which could be developed in the axle with a high-reduction gear train as used here, when the entire engine torque, multiplied, was applied to a single driving component. An axle has been shipped to Fort Churchill and the remainder of the winter tests will be run by the ERDL Test Team.

When using the tracks with the trailer towed, the Galanot track articulation appeared to be excellent, and no failures were observed. The trailer tracked perfectly, tires stayed inside the retainers, and no excessive wear or interference was observed. However, with even a few degrees turn under power to the trailer, malfunctioning of the tracks occurred. The wheels bent over the retaining pads, Figure 23, attempting to climb out of the "trough" formed by the tracks. Occasionally, a retaining pad cut deeply into the tires. Unretained steel bushings in the articulating bearings of the tracks were literally extruded from their rubber mountings (Figure 24). No sharp, short radius turns were attempted with power-to-the-trailer, as it was apparent that the trailer would successfully shed the tracks.

The speed ratios of the tractor and trailer tracks is such that the trailer, when powered, overtravels the tractor. That is to say, small slippage of the trailer tracks is inherent in the design. It is considered that is the probable reason for the wheels trying to escape the tracks on turns. If so, with equal speed of the tractor and trailer tracks, it is probable that the observed self destructive actions will not reoccur. This could be established only by modification and further testing.

CONCLUSIONS

1. The developed trailer appears to be entirely satisfactory for conducting all proposed tests, except for turning tests with power-to-the-trailer and Galanot tracks.

2. A new landing gear should be construction or obtained in the future; this is not important in the proposed tests.

3. Considerable additional traction over that from the tractor alone can be obtained by powering the trailer; how much is yet to be established.

4. Ground action of the Galanot tracks in snow at slow speeds with the trailer powered is superior to that of the tractor alone at relatively higher speeds.

5. It is possible to negotiate steeper hills (in snow) with trailer and tractor both powered than the tractor alone pulling.

6. The present tractor-drawn prototype trailer is a satisfactory cargo carrying device for winter arctic use, when the trailer is towed.

7. The tractor-drawn prototype when powered is a satisfactory cargo carrying device with Galanot tracks if no turns are attempted with power to the trailer tracks.

8. As fitted, excessive torque to one track from slipping of other tracks will probably cause failures of the type experienced.

9. Extrusion of track bushings (Figure 24), can probably be prevented in future models by redesigning the holding parts.

APPENDIX C

REPORT OF TEST OF ARCTIC CARGO TRAILER AT
FORT CHURCHILL, CANADA, SUMMER 1954

AND

ANALYSIS OF THE GROUND AT THE TEST SITE,
CORNELL UNIVERSITY

CORPS OF ENGINEERS CLIMATIC FIELD TEST TEAM
FORT CHURCHILL, MANITOBA, CANADA

10 August 1954

SUBJECT: NAVCERELAB Arctic Cargo Trailer

TO: Chief, Climatic Test Branch, Fort Belvoir, Virginia

1. Following receipt of replacement parts for the Arctic Cargo Trailer, the trailer was repaired and readied for the summer phase of the Arctic Test Plan.

2. Following a thorough maintenance inspection of the Navy D-8 Tractor and the Arctic Cargo Trailer, a gross load of 30,000 pounds was loaded on the trailer. A three mile route across the tundra (muskeg) was laid out in a northerly direction from the Engineer Test Team South Camp area. The route was chosen because of the fact that there is a sloping hill gradually changing to an approximately 45 degree slope in a straight line from South Camp.

3. After proceeding approximately one third of the distance to the hill (about 3/4 of a mile), the D-8 Caterpillar bogged down in the muskeg. At this time the power was transferred to the Arctic Trailer drive and by this means successfully extricated itself. Upon examination of the terrain, it was decided by the Engineer Aide that the Caterpillar D-8 and the Arctic Cargo Trailer should be able to complete the remainder of the distance to the hill selected for the stalling test. The operator then proceeded in the direction indicated and was nearly half way across when the Caterpillar again became mired. After shifting the power take-off to the Trailer drive an attempt was made to push the tractor enough to clear it from the mire. Before the tractor had made any progress the Trailer had lost its driving power. It was found that the drive chains on the two rear duals had broken and the chain on the left front dual was also broken. Due to the fact that no spare drive chains were on hand it was impossible to repair on replace them.

4. It was then necessary to send for a tractor from the Engineer Test Team to try to pull the D-8 and the Arctic Cargo Trailer out of the muskeg. Upon trying to extricate the

tractor and trailer from its position, it was found that one tractor was incapable of doing the job (Figures 25 and 26), so two more tractors had to be sent out to the scene before freeing the tractor and trailer. The unit was then pulled to more solid ground where it was able to return to South Camp under power of the NAVCERELAB D-8 Caterpillar Tractor.

5. When the three tractors from Engineer Test Team were attempting to tow the tractor and trailer unit from the muskeg, it was necessary to hook to the trailer itself attempting to winch the trailer out of its position. While doing so, the sixteen (16) 5/8" bolts holding the rear drawbar structure sheared off and the structure was pulled off the trailer.

CONCLUSIONS

1. In the opinion of the operators and engineer aides, the Arctic Cargo Trailer in itself has sufficiently low ground pressure to enable it to travel across muskeg. Most important to efficient operation of the Cargo Trailer would be a low ground pressure tractor for the prime mover.

2. The "U" Bolts holding the bed of the trailer to the frame are of too small a diameter, allowing the bed to shift on the frame both fore and aft and sideways.

3. If possible, the power take-off unit should be reversible to enable the trailer to exert a pull on the tractor as well as a forward power movement. It is felt by the operators that by reversing the power of the trailer itself, it would at times be easier to extricate itself from extra soft spots than with only the forward power drive.

4. The rear drawbar framework should be strengthened to avoid the possibility of its pulling off during extrication operations.

A complete analysis of the ground, soil, and vegetation at the scene of the breakdown has been compiled by a group from Cornell University who are at this station making a six weeks' study of soil conditions here. This report, together with photographic coverage (Figures 25 and 26) is included as a part of this report.

HARRY M. CURRAN
M/Sgt RA 16323462
Operations NCO

ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
CORPS OF ENGINEERS CLIMATIC FIELD TEST TEAM
FORT CHURCHILL, MANITOBA, CANADA
CORNELL UNIVERSITY TESTS

12 August 1954

SUBJECT: Soil Tests of Muskeg in Area of Arctic Cargo Trailer Breakdown

TO: Chief, Climatic Test Branch, Fort Belvoir, Virginia

A total of four test sites (see Figure 27) were picked to determine moisture content, dry density, wet density, and penetrometer readings. At each test site a soil cross-section (see Figure 28) was also taken and the following values determined:

		After one pass by vehicle
Surface	20	30
6 inches	100	140
12 inches	160	40
18 inches	190	60
24 inches	110	95
30 inches	100	340

From the above penetrometer readings it was found that the existing strata was abnormal between 18 inches and 24 inches before the vehicle passed over the site.

At test site No. 2 we found a remolding index of 0.246 and the following penetrometer readings:

		After one pass by vehicle
Surface	40	35
6 inches	70	130
12 inches	140	60
18 inches	60	60
24 inches	120	90
30 inches	140	340

From the above readings we found this to also be an abnormal area and the critical layer to exist between 12 inches and 18 inches before the vehicle passed over the site.

It can be noticed from all the above tests that the critical layer shifts upward after the vehicle passed over the test site. This was so at every test site.

At test site No. 3 we found a remolding index of 1.375 and the following penetrometer readings:

		After one pass by vehicle
Surface	20	30
6 inches	80	120
12 inches	200	35
18 inches	50	60
24 inches	110	70
30 inches	140	80

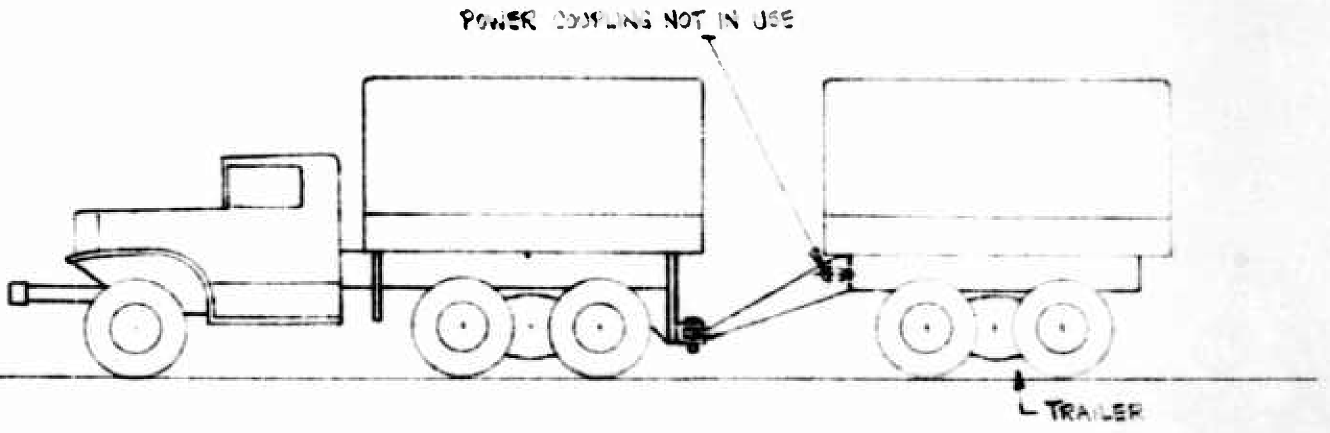
It was found that a critical layer existed between 12 and 18 inches and the soil was abnormal in character, before the vehicle passed over the site.

At test site No. 4 no remolding Index was determined due to the high degree of lateral flow of the soil. When the remolding cylinder was forced into the soil and then withdrawn, there were not enough samples with which to conduct the test. However, penetrometer readings were taken and denoted the following:

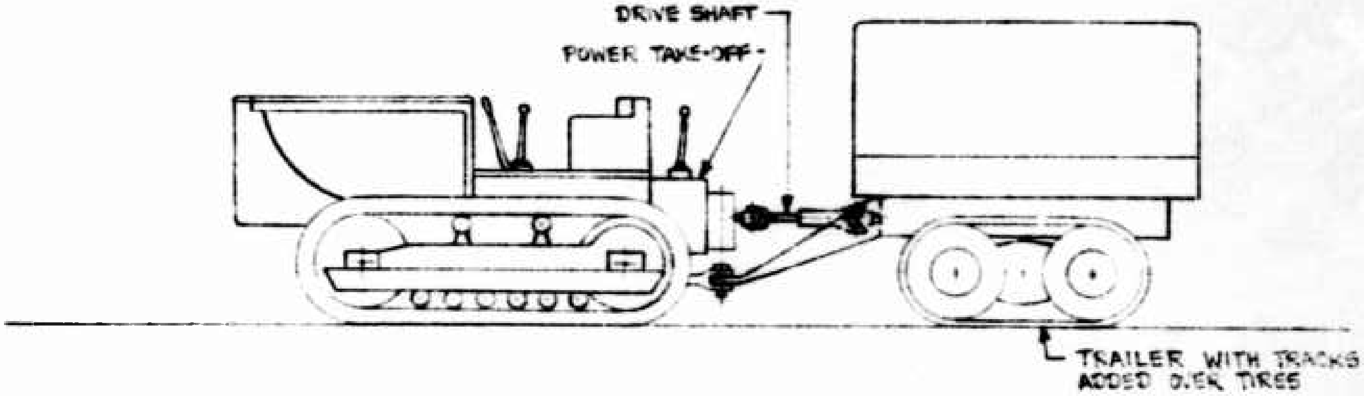
Surface	15
6 inches	20
12 inches	60
18 inches	20
24 inches	80
30 inches	340 (rock)

As can be seen the readings were extremely low which accounted for the sudden bogging down of the vehicle.

J. QUARTARARO
Cornell University



POWERED TRAILER (AT HIGH SPEED POWER COUPLING NOT USED)



POWERED TRAILER (AT LOW SPEED POWER COUPLING IN USE)

PORT HUENEME NAV CERELAB CALIF		
DRWN. D.Taylor / DATE 1/13/51	POWERED TRAILERS	
NO SCALE	NY 013 007-1	Fig. 1

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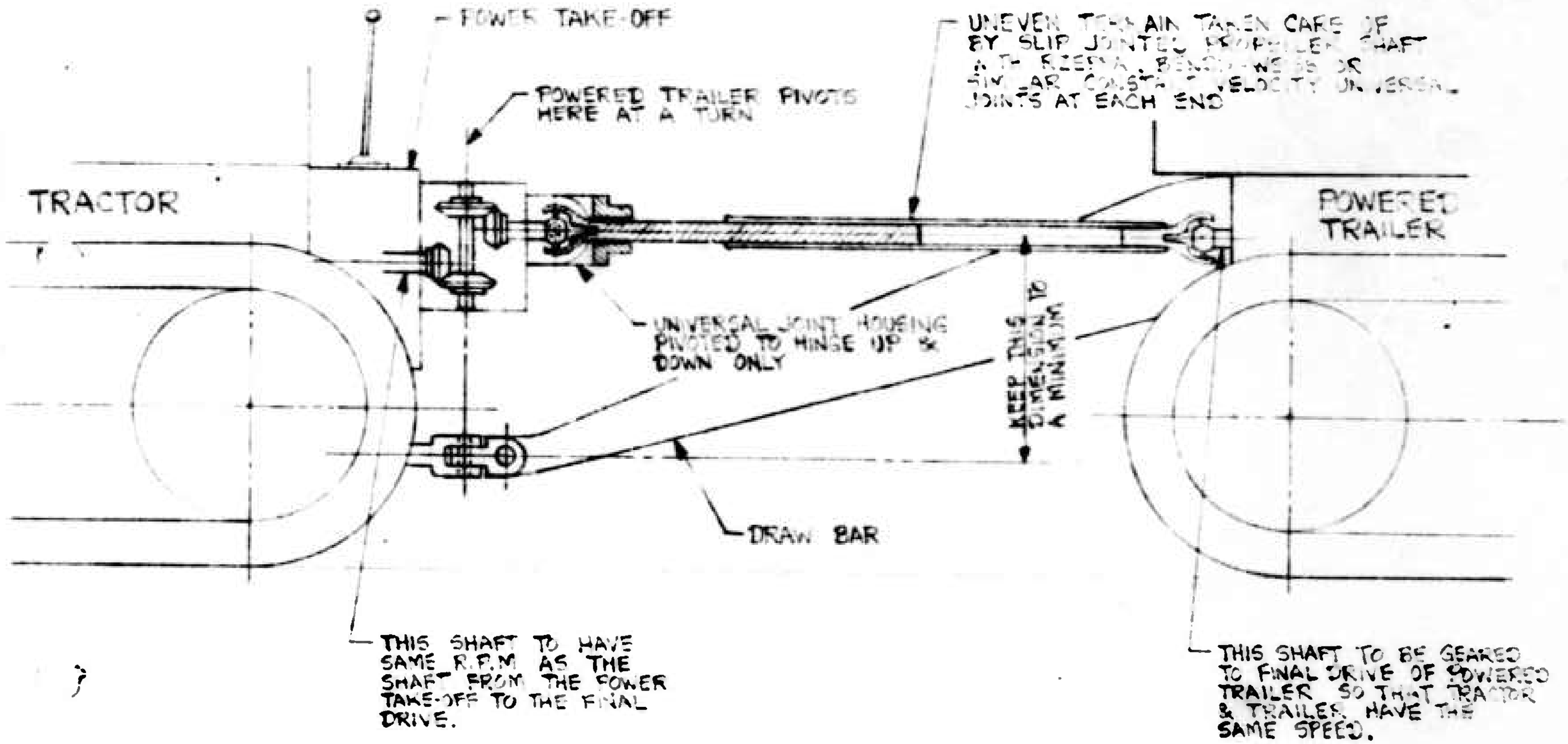

PORT HUENEME NAVCERELAB CALIF.

DRWN D. Taylor

DATE 11/29/50

POWERED TRAILER PROPELLER SHAFT

NO SCALE | NY 013 007-1 | Fig. 2

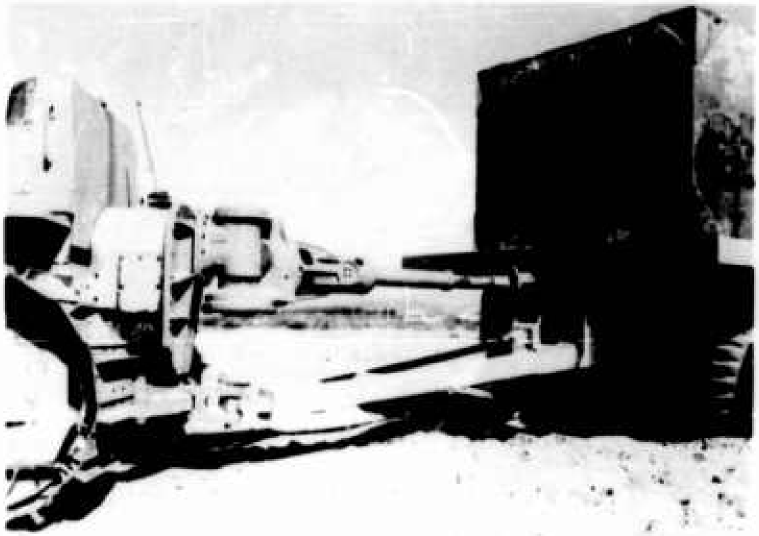

Figure 3. Power train between tractor and trailer. Power is transmitted to trailer by shifting lever at top of power take-off. Powered universal joint transmits torque only. Axial forces are transmitted by towbar.

Figure 4. Undercarriage of Experimental Arctic Cargo Trailer.

Figure 5. Experimental Arctic Cargo Trailer (with Galanot Tire Tracks).

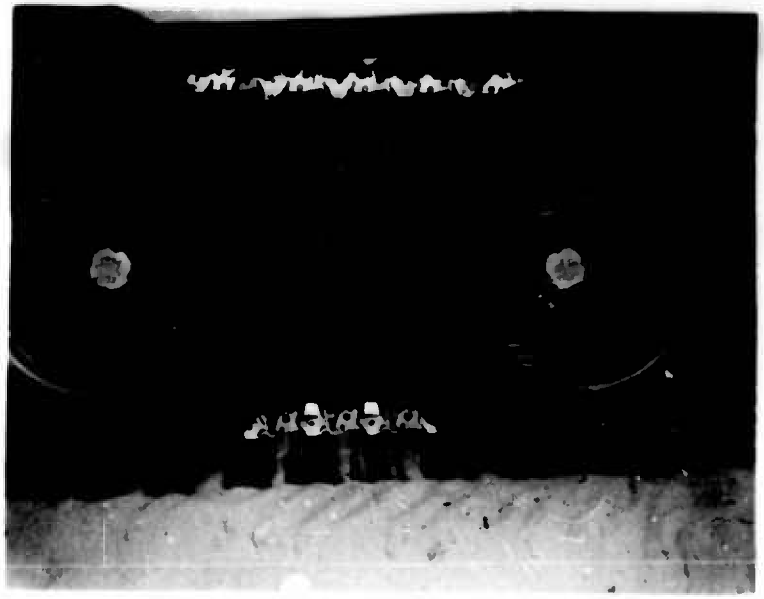

Figure 6. Side view of tire tracks installed on dual tandem wheels.

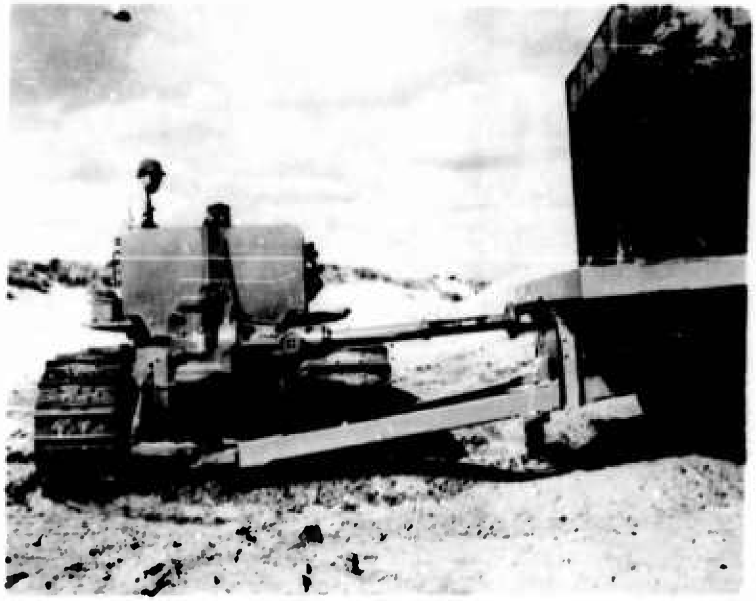

Figure 7. Horizontal articulation of trailer connection almost 90 degrees.

Figure 8. Close-up of powered universal joint and power take-off.

Figure 9. The 15-ton Athey Forged-Trak Trailer towed by D8 Caterpillar tractor.

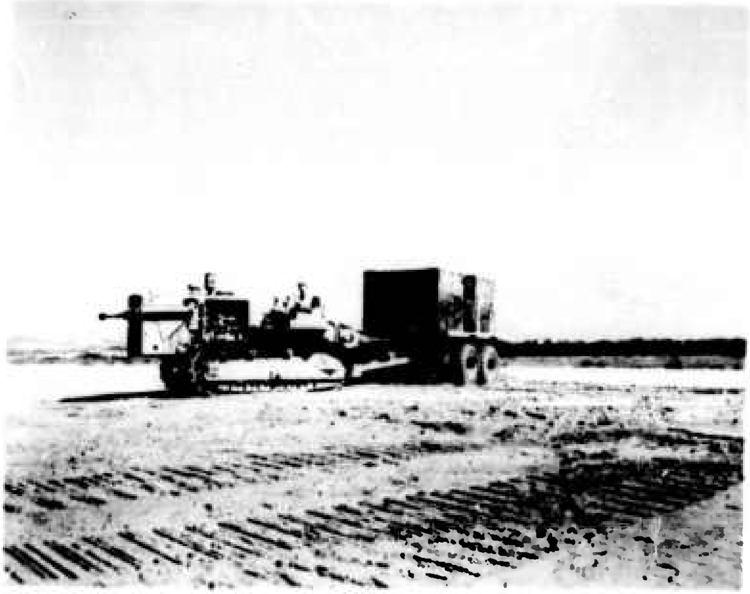

Figure 10. Experimental Arctic Cargo Trailer (without Galanot Tire Tracks) coupled through powered universal joint to D8 Caterpillar tractor with Wood power take-off transmission CW 240 (15-ton load).

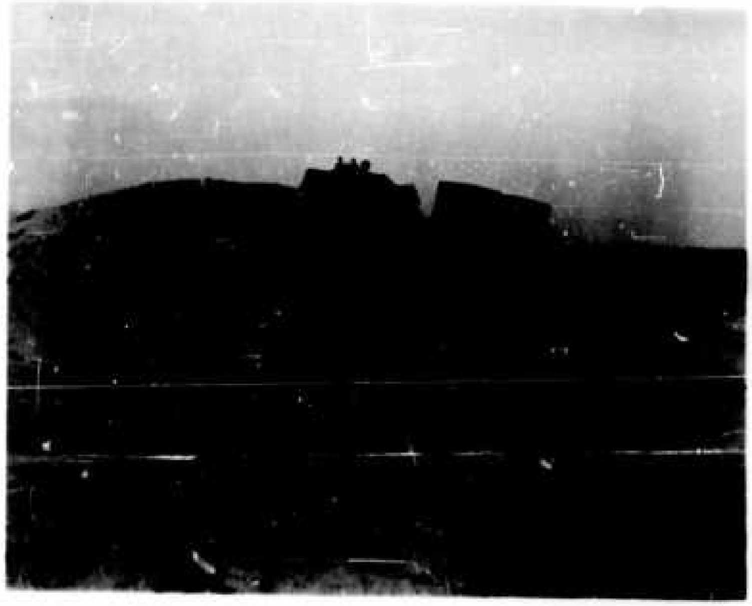

Figure 11. D8 Caterpillar Tractor pulling 15-ton loaded Athey Wagon up a 25 per cent grade. Experimental Arctic Cargo Trailer with tracks was able to negotiate this slope with a 10-ton load without power to the trailer, and with a full load of 15 tons only when the trailer was powered.

Figure 12. Experimental Arctic Cargo Trailer and 15-ton Athey Wagon at the base of a 35 per cent slope prior to comparison test. Each unit is loaded with 15 tons of cargo.

Figure 13. Athey Wagon unit stalled on 35 per cent grade almost immediately, while powered Experimental Arctic Cargo Trailer continues to move forward near top of slope.

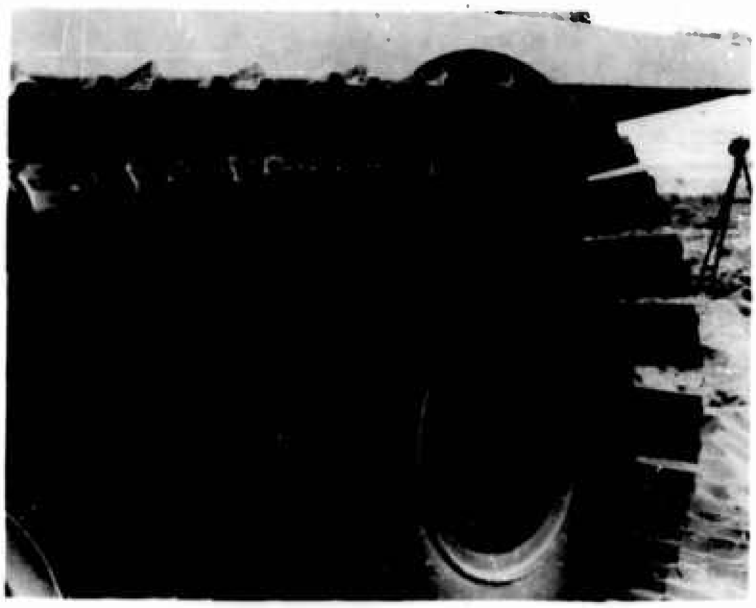

Figure 14. Insufficient clearance between tracks and cargo bed allowed tracks to hit cargo bed after tracks slipped on wheels. As a result of this test cargo bed was raised three inches.

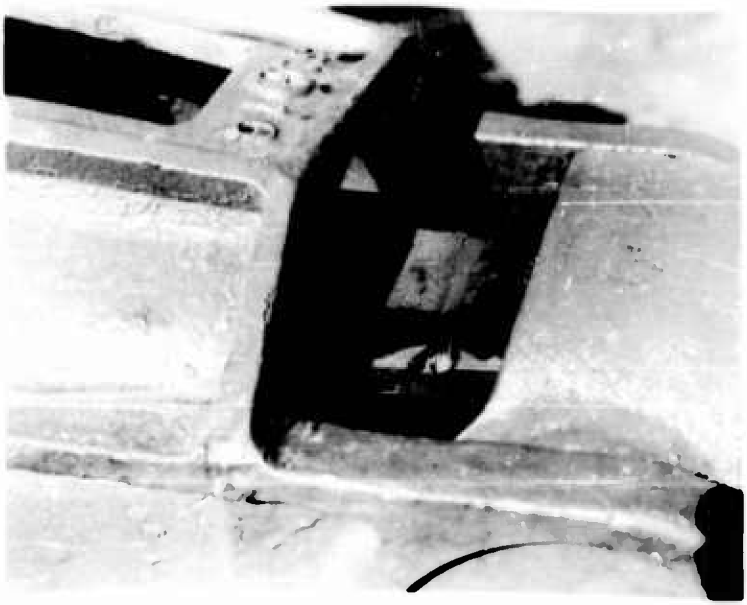

Figure 15. Close-up of gouging of shaft connection caused by limited vertical articulation of the Powered Universal Joint. Universal joint yoke and the cylindrical housing were modified later to allow a greater angle of articulation.

Figure 16. The need for an improved tire track was demonstrated by the slipping of the tracks on the dual wheels. As a result of this finding, a set of tracks with a double row of connector assemblies was purchased for the later tests.

Figure 17. The tire tracks with single connector assembly have a tendency to slip on the wheels on side hill operation.

Figure 18. Experimental Arctic Cargo Trailer was tested on the soft ground adjacent to a tidewater slough. The unit was fully loaded to 15 tons and demonstrated its ability to compete well with this terrain without transmitting power to the trailer.

Figure 19. Close-up of articulation of Powered Universal Joint as allowed after modification. Trailer is loaded with 15 tons and successfully negotiated the test condition illustrated. The 15-ton Athey Wagon failed in this test.

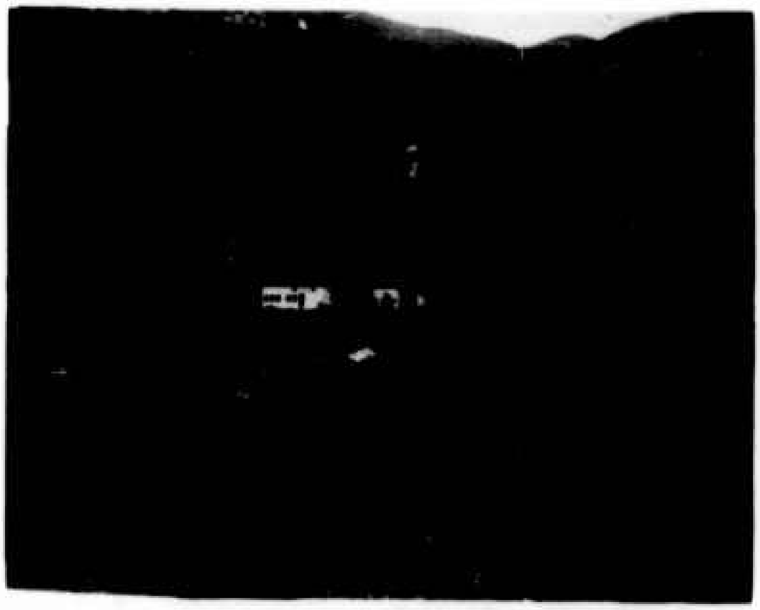

Figure 20. Close-up of hitch after completion of mud tests. Towbar was straightened and reinforced later.

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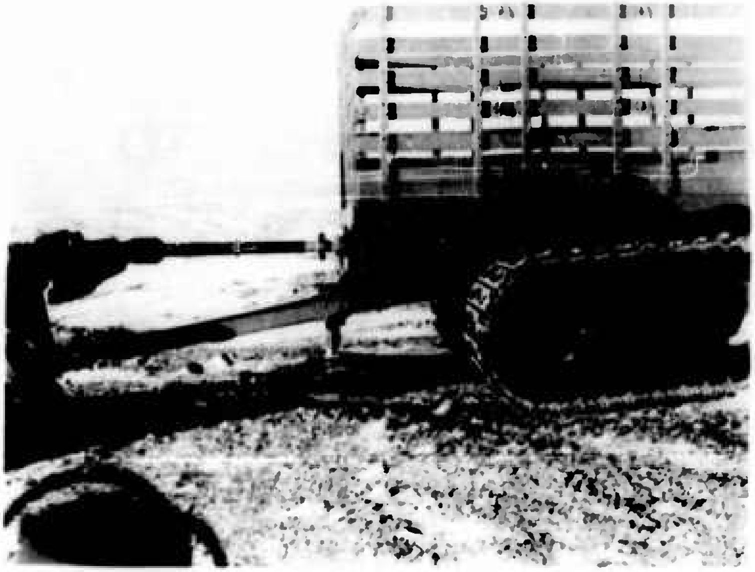

Figure 21. Arctic Cargo Trailer preparing to descend 15 degree slope at Fort Churchill, 13 February 1954.

Figure 22. Broken rear axle of Arctic Cargo Trailer looking from behind the trailer.

Figure 23. Deformed retaining pads on Galanot tracks after attempts to turn with power applied to Cargo Trailer, Fort Churchill, February 1954.

Figure 24. Steel bushings and rubber mountings from Galanot tracks. The bushings fell out during tests at Fort Churchill, February 1954.

Figure 25. Close-up of trailer tracks mired in tundra at Climatic Field Test Site, Fort Churchill, Manitoba, Canada.

Figure 26. Caterpillar D8 Tractor and Experimental Arctic Cargo Trailer bogged down to 36 inches deep in tundra (muskeg) at Climatic Field Test Site, Fort Churchill, Manitoba, Canada, in July 1954. Rescue tractor in foreground is mired also.

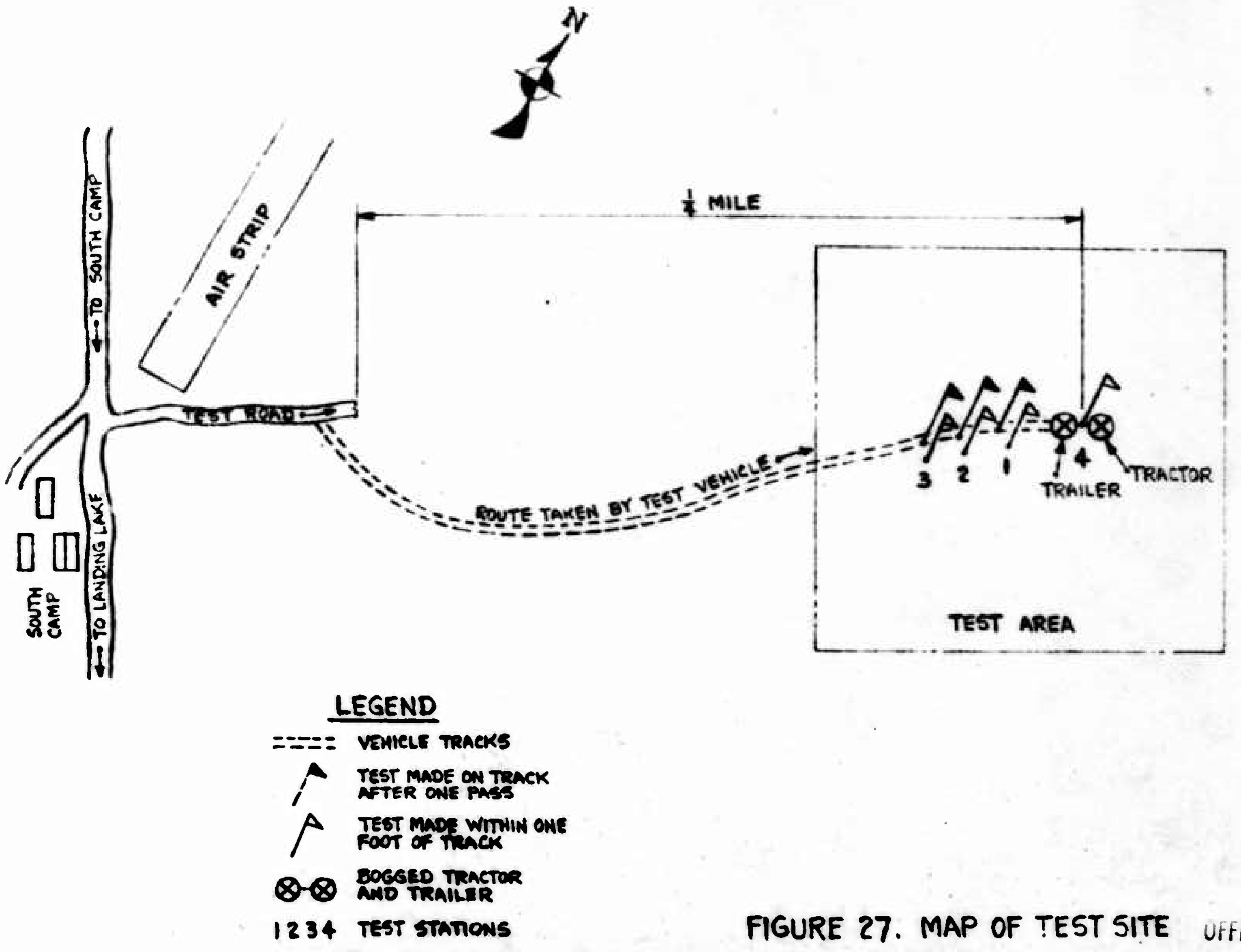

FIGURE 27. MAP OF TEST SITE

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SKETCH OF SOIL CROSS-SECTIONS IN TEST AREA

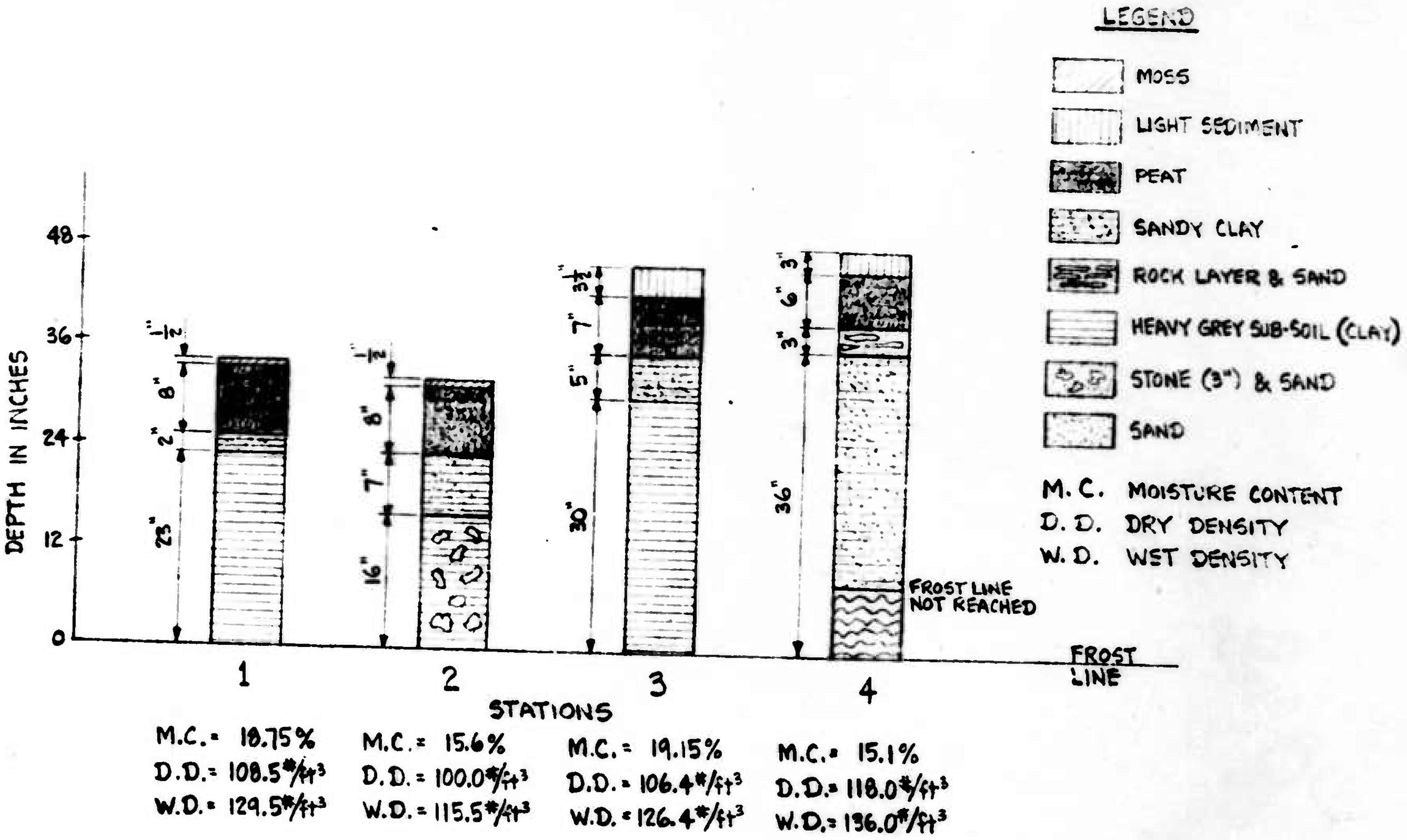

FIG. 28